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AN IMPROVED METHOD FOR CONVERTING AN OBSERVED SKEIN STRENGTH OF COTTON YARN TO THE STRENGTH OF A SPECIFIED YARN COUNT

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CONTENTS

INTRODUCTION

By manufacturing cotton into yarn under known conditions, observing the behavior of the material during processing, and measuring the physical properties of the product, an investigator can obtain much information about the usefulness of the cotton for specific purposes. Experimental spinning is thus one of the most valuable instruments used in conducting research on cotton-fiber quality.

With the possible exception of waste content, yarn strength, at present, is one of the most important factors to be considered in the determination of cotton quality by means of the spinning test. From the agricultural viewpoint, a consideration of the strengths of yarns spun from two or more cottons points the way toward the selection of the best varieties to be grown, the best cultural practices to be employed, and the best ginning technique to be used, if lint of the highest quality is to be produced.

In fundamental studies of cotton quality, strength of yarn is the medium through which the significance of such physical properties of fibers as length, strength, width, and weight per unit length, can be determined. Without some means of determining the effects of differences in such factors upon the physical properties of the manufactured yarns and fabrics, the value of these studies would be very limited.

The spinning test is a device with which the spinner has long been familiar. He appreciates the importance of accurate yarn-strength

[1] This study is one of a series in the program of work of the Cotton Utility and Standards Research Section under the leadership of R. W. Webb.

81442°—36——1

data for upon such data he bases, in a large measure, his selection of the cotton he will use, and the organization, speeds, and settings he will employ in the mill.

Different spinning laboratories spin different counts of yarn in their regular operations. It is impossible in spinning to obtain an exact specified count of yarn. Observed yarn-strength data are thus not comparable, and it is difficult to place the results of two laboratories on the same basis for comparison.

Some method is necessary to express observed strengths in terms of strengths of a desired specific yarn count. It is believed that the use of the method recommended in this bulletin for converting skein strengths to strengths of specific yarn counts, will considerably increase the usefulness of data resulting from spinning tests.

With proper planning of the counts to be employed in a spinning test and with the use of the conversion formula here given, time and effort can be saved by spinning only a few extreme numbers and interpolating or extrapolating for the probable strengths of other counts. Care should be exercised, of course, not to exceed the spinnable limit of a particular cotton.

VARIABILITY OF YARN SIZE

A study of the yarn data derived from spinning tests conducted under the mill conditions or in the laboratory shows for each lot tested an appreciable degree of variation in the counts of the yarn. Extreme care may be exercised in processing and handling the material to produce a specified count, but lack of perfect control of the fibers during drafting prevents the making of a yarn that is absolutely uniform in weight and diameter. In analyzing the dispersion of size in 25 skeins of each of 1,969 carded yarns at the spinning laboratory of the Bureau of Agricultural Economics, it was found that the average percentage of mean deviation of size was 1.98 ± 0.01 percent. That is, if the sizes of the skeins in a series averaged 22.00s, and all of the observations deviated from the average to the same degree, approximately one-half of the skeins would average 21.56s in size, and the remainder would average 22.44s. The total spread of sizes would be greater, ranging from, say, 20.75s to 23.25s.

Furthermore, although the specified or "nominal" count of yarn for a particular test may be designated as 22.00s, the average usually falls either below or above this mark. This variation is due, in part, to the limitations of commercial spinning equipment.

Once the material is ready to be spun, the size of the draft-change gear at the spinning frame is the major factor in determining the size of the resulting yarn, although a number of minor factors influence the size, such as character of the cotton, twist inserted, weight of traveler, and humidity. A consideration of the size of the roving from which the yarn is to be spun, the count of yarn desired, and the draft constant of the machine may indicate that a draft gear with 40.5 teeth, for example, would be required to produce, say, 22.00s. Obviously, the choice of gears is limited to a 40 or a 41. The average size of the resulting yarn will be about 22.27 or 21.73, depending upon whether the smaller or the larger gear is used (assuming that no crown gears are available, as is frequently the case). Thus, to the deviation in size mentioned above may be added an original

variation from the specified count, which under ordinary circumstances may be as large as 2 percent of the count.

It is a well-known fact that, other things being equal, the finer the count of a yarn the lower will be the tensile strength in the skein, or lea, test, as well as in others. Hence it is not difficult to see that the unavoidable variation in the size of a series of skeins of yarn will undoubtedly affect the individual skein strengths and, in most cases, the average of the strengths. When the spinning utility of two cottons is under comparison the differences in strength may be obscured or even apparently reversed if no cognizance is taken of the effects of deviations and variations in size from the specified count. It is customary, therefore, both in routine mill-spinning tests and in laboratory research, to employ some method of "correcting" the yarn strengths with a view to eliminating the effects of differences in size.

YARN-STRENGTH CORRECTION METHODS

REVIEW OF LITERATURE

Balls (*5*)[2] describes two methods employed for correcting yarn-strength data to a specified or nominal count. The first involves the use of a count-strength correlation diagram in which the yarn data are plotted as a scatter diagram with size values as ordinates and strength values as abscissas. The line best representing the relationship of strength to count is drawn by inspection, and the point at which this line crosses the horizontal line representing the nominal count is taken as indicating the corrected strength of the yarn. The disadvantage of this method of correction lies in the fact that it is frequently difficult if not impossible to place the line with any degree of assurance that it represents the relationship even approximately. Thus, in many instances little if any benefit is likely to result from changing the strength values according to this method. In considering his 13 samples, Balls found only three cases in which the scatter diagrams indicated clearly the correlation of the two properties.

Balls pointed out that in the routine of mill testing rooms various formulas with rational bases are used for correcting yarn strengths to nominal counts. The simplest of these is in many ways the most convenient, and requires merely the ascertaining of the product of strength multipled by the count. These products of two or more cottons (instead of the strengths themselves) are compared when studying the relative strengths of various yarns. This method assumes a constant inverse correlation between strength and size.

Turner and Venkataraman (*13*) made use of the count-strength products in their study of the comparison of skein and single-yarn tests, and Turner (*12*) had employed the count-strength product in a previous study. But in neither of the two papers was the usefulness or the statistical significance of this measure discussed.

At present, Ahmad (*3*) is employing the count-strength product in his work at the Indian Central Cotton Committee Technological Laboratory at Bombay. In discussing the spinning value of cotton Ahmad says (*3, pp. 18–19*):

> It will be seen from the above discussion that, instead of using the actual values of lea-breaking strength, the count-strength products are employed in ascertaining the spinning value of a cotton. This is done with a two-fold object. In the first

[2] Italic numbers in parentheses refer to Literature Cited, p. 17.

place, no matter what precautions are taken, the actual counts (of yarns tested) are bound to differ by a small amount from the nominal counts. This may be due to varying conditions of humidity or to lack of uniformity in a yarn. This departure from nominal counts will affect the breaking-strength of a yarn; if the actual count be higher, its strength will be less and, *vice versa*, if the yarn be heavier, it will break at a higher tension. In order, therefore, that the results for yarns spun into identical counts may be strictly comparable, it is necessary either to reduce the observed values to nominal counts in each case or, what amounts to the same thing, to use count-strength products. This procedure is based on the assumption that, within the small range of deviation of actual from nominal counts, strength of a yarn will vary sufficiently regularly to allow the principle of proportionality to be applied. The second reason for employing the count-strength products in preference to strength-values lies in the fact that changes in humidity affect the counts and breaking strength of yarns in opposite directions—increase in humidity decreasing the counts and increasing the strength. If, therefore, the count-strength products are employed in comparing the performance of cottons, the variations due to small changes in humidity are smoothed out.

Herzfeld (*7, p. 96*) goes so far as to state: "The tensile strength in materials of identical constitution varies inversely with the yarn numbers." He further says that 20s yarn will have double the strength of 40s yarn (single-thread tests). The fallacy of such a broad statement is at once apparent, however, to anyone who has examined strength data of yarns spun from the same material into widely different counts.

When comparing the strengths of two yarns spun with two different types of bobbin wind, Cobb (*6*) eliminated the size variable by selecting from his two series of breaking strengths only those for which identical sizes were recorded on the same day. Of the total of 812 breaking strengths, 506, or 62 percent, were thus rejected, the weights of skeins having been recorded to the nearest half grain. If the strengths of three or more yarns were being compared by this method, the percentage of rejected observations would be greatly increased, thus requiring an enormous amount of work for a limited quantity of usable results.

In a majority of the cases examined it was found that published reports of routine spinning tests employed either the count-strength product or a single formula based upon the same assumption, namely, that strength and count are inversely proportional within limits wide enough to include the extremes of the usual spinning-test data. In 1920 Taylor and Earle (*11*), in a spinning-test report published by the United States Department of Agriculture, presented yarn-strength data that had been corrected by this means, and in all subsequent reports of like nature issued by the Department the same system has been followed. Commercial establishments (*2, 9*) also use these methods of obtaining corrected strengths in their cotton-spinning research work.

The Empire Cotton Growing Corporation (*1*) has corrected to specified count not only the strength data but also data regarding work of rupture, on the assumption of inverse proportionality between these measures and the counts. The statement is made:

> In comparing yarns for lea strength and work of rupture it is necessary to take into account the small differences in the actual count which, as noted above, are unavoidable. This is done by means of the products, lea strength × actual count, and work of rupture × actual count; these products can only be used in comparing yarns whose actual counts do not differ by more than about 5 percent.

FAULTS IN METHOD USUALLY USED

The usual method of correcting skein strengths has been adopted as a standard by the American Society for Testing Materials (*4, p. 49*). The book of standards published by that society states that the average tensile strength shall be corrected to the specific size by multiplying the actual average strength by the quotient obtained by dividing the actual average size by the specified size.

A variation of the method described consists in calculating the breaking strength per grain of yarn and then determining the corrected strength of the specified count by assuming that the breaking strengths are directly proportional to the weight in grains of the observed and specified counts of yarn.

The usual procedure in correcting the skein strength of a yarn to a specified count consists in multiplying the average of a series of strength observations by the average count obtained from the same skeins of yarn and dividing the resulting product by the specified count. When a measure of the reliability of an average breaking strength is required, as when it is to be compared with some other average, it is desirable to correct each observed breaking strength to the specified count before averaging. In either case the correction is made according to the equation

$$S_2 = \frac{C_1 S_1}{C_2}$$

in which S_2 is the corrected skein strength, C_1 is the observed count, S_1 is the observed skein strength, and C_2 is the specified count.

This formula for correcting skein strengths may be derived from a theoretical consideration, since in a given length of yarn the count is a reciprocal of the quantity of cotton in the yarn. Then if strength is an additive function of quantity, the equation

$$CS = K$$

where K is a constant and the other symbols have the same significance as above, should be valid. Thus the strength of two yarns of different counts would be

$$S_1 = \frac{K_1}{C_1} \text{ and } S_2 = \frac{K_2}{C_2}$$

and

$$S_1 : S_2 :: \frac{K_1}{C_1} : \frac{K_2}{C_2}$$

Since for a given cotton, other variables being held constant, K_1 and K_2 would be identical; and the equation would become

$$S_1 : S_2 :: C_2 : C_1$$

or

$$S_2 = \frac{S_1 C_1}{C_2}$$

Such a relation is shown graphically by curve *a* in figure 1. The count-strength product is seen to be a constant, regardless of the count of yarn.

Actual tests will show, however, that K is not the same for different counts but is variable, and a relationship similar to that represented by curve *b* in figure 1 is noted. If a number of different counts of yarn are spun from the same cotton, with the same twist factor, it will be observed that the count-strength product decreases rapidly as the count becomes finer. A line connecting the plotted points will

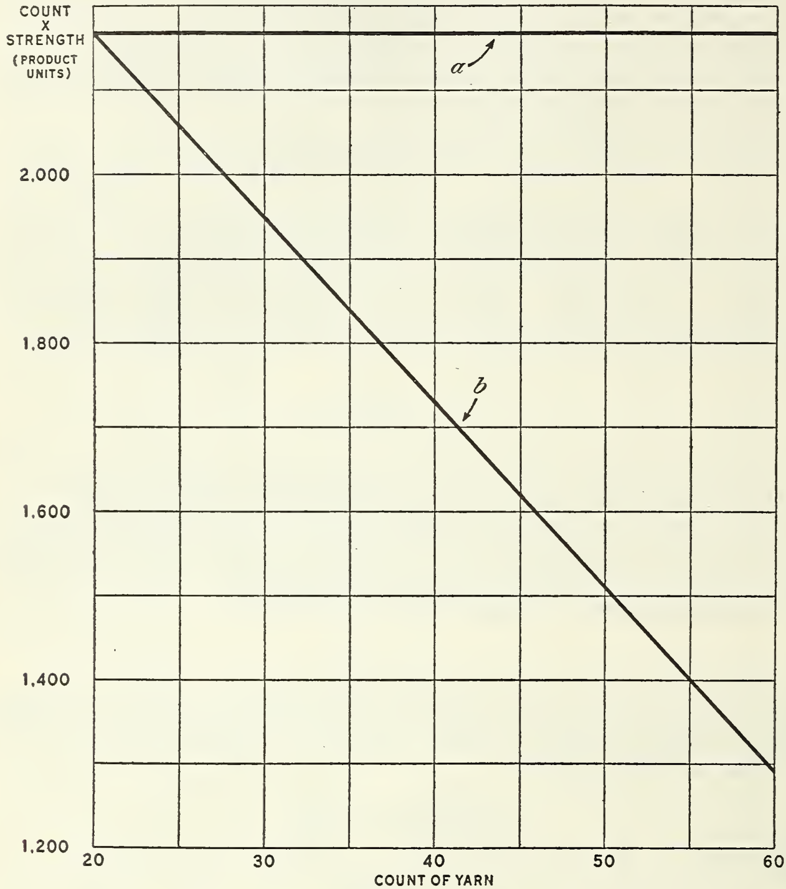

FIGURE 1.—RELATIONSHIP BETWEEN COUNT-STRENGTH PRODUCTS OF YARNS OF DIFFERENT COUNTS.

Line *a* reflects the assumption that the count-strength products (K) is constant throughout the range shown, an assumption commonly made. Line *b* plots the average course of count-strength products found in actual tests of a large number of cottons of 1-inch staple. The product decreases as the yarn count increases.

be practically straight, if the number of observations represented by each point is great enough. The probable count-strength product for any count between the extremes of the available data can be obtained, therefore, by interpolation.

Figure 2 represents an enlarged section of a count-strength product diagram. For the purpose of illustration, it will be assumed that a skein of yarn has been found by test to have a size of 26.5s and a breaking strength of 70.0 pounds. A count of 28s will be taken as the

specified or nominal size. It is required, therefore, to determine the probable strength of a skein of 28s spun from the same cotton with the same twist factor as that of a skein of 26.5s that broke at 70.0 pounds. By the use of the common method of correcting strength to size, the observed strength is multiplied by the observed size; and

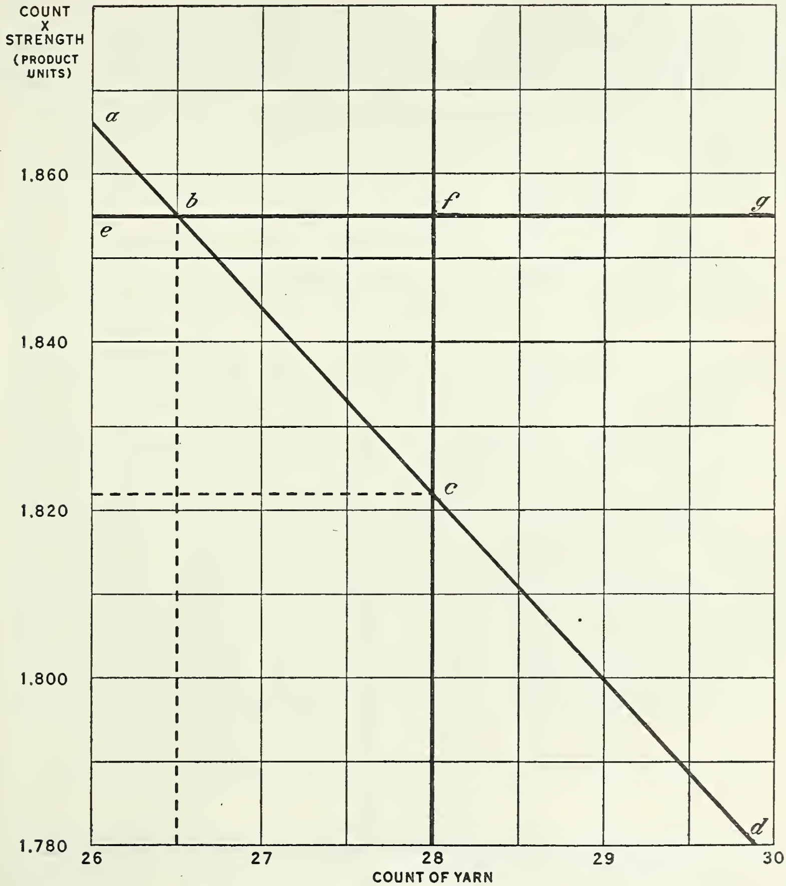

FIGURE 2.—COMPARISON OF METHODS OF CONVERTING OBSERVED COUNT AND STRENGTH TO PROBABLE STRENGTH OF A HIGHER COUNT YARN.

The test yarn had a count of 26.5 and skein-strength of 70 pounds, which gives a product of 1,855 plotted at *b*. The most probable count-strength product for a 28s yarn lies at *c*, rather than *f*, which is plotted on the common assumption.

this product (which is the count-strength product) is divided by the specified count. This method gives

$$\frac{70\times 26.5}{28}=66.25 \text{ pounds (corrected to 28s)}$$

The count-strength product, 70×26.5, is found to be 1,855. The point represented by a count-strength product of 1,855 and a count of 26.5 is shown at *b* in figure 2. In making the correction in the usual way, the value at *b* is in effect moved along the horizontal line *eg*, representing a constant count-strength product of 1,855, to the

point *f*, at 28s on the abscissa. Thus the product has remained unchanged; and by dividing it by the specified count, the corrected strength is obtained.

If the correction had been made with due regard to the true relation of count-strength product to count, the point *b* would have been moved downward and to the right to *c* on the curve *ad*, which represents the count-strength product curve for the particular cotton under consideration. By projecting the point *c* to the ordinate, a count-strength product of 1,822 is found, which when divided by 28 gives

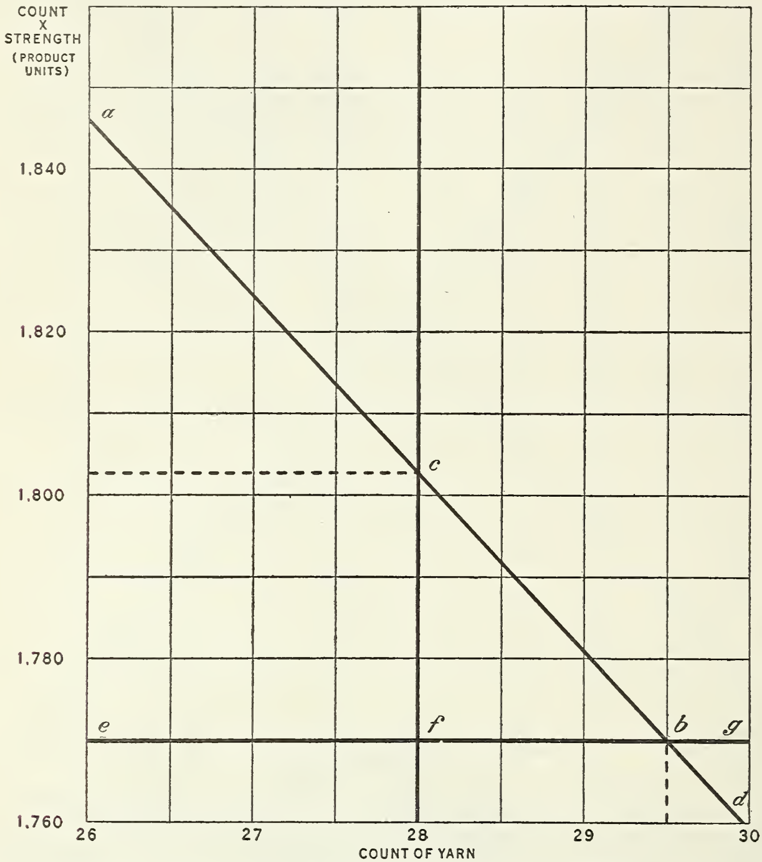

FIGURE 3.—COMPARISON OF METHODS OF CONVERTING OBSERVED COUNT AND STRENGTH TO PROBABLE STRENGTH OF A LOWER COUNT YARN.

In this case the probable strength of the 28s yarn (indicated at *c*) obtained by the improved method is greater than that obtained by the common method indicated at *f*. The difference is 1.15 pounds or 1.79 percent greater than the strength of the test yarn plotted at *b*.

a corrected strength of 65.07 pounds as compared with 66.25 pounds obtained above. The former is 1.18 pounds less than that obtained by the usual method, or it may be said that the value obtained by the generally accepted method is too large, in this instance, by 1.81 percent.

As a second example, it will be assumed that a skein from the same batch, sized 29.5s and broke at 60 pounds. The specified count

remains the same; namely, 28s. The values involved are shown graphically in figure 3.

By the usual method

$$\frac{60\times 29.5}{28}=63.21 \text{ pounds (corrected to 28s)}$$

A count-strength product of 1,770 is found by completing the multiplication in the numerator. This product and the count, 29.5s, are plotted at *b* in figure 3. To obtain the value mentioned, the point *b* is moved horizontally to *f*, above 28s on the abscissa, and in so doing it is clear that the product remains unchanged. The point *b* should have been moved upward and to the left to *c*, representing 28s yarn, and the projected value of the count-strength product should have been read as 1,802+. This product, divided by 28, gives 64.36 pounds as the corrected strength, which is 1.15 pounds more than that obtained by the generally accepted method. In other words, the result by that method is too small, in this particular instance, by 1.79 percent.

From the two foregoing examples it is clear that the usual method of correcting strength to specified count injects an error, the result being too large if the observed count is less than the specified count and too small if the observed count is greater than that specified. If it happens that the average of a series of sizes falls upon or nearly upon the specified count and the number of observations is great enough, the effects of the correction errors will be negligible, since it is probable that the negative errors will cancel the positive errors. However, the variation among the corrected strengths when the usual method is used will be smaller than the true variation, and statistical analyses for significant differences will thus be affected. If the average size is heavy, the corrected strength will be too high; and conversely, if the average size is light, the corrected strength will be too low. The size of the error will depend upon the extent to which the actual size deviates from the specified size.

NEW CONVERSION FORMULA

DEVELOPMENT

When conducting a routine spinning test it is obviously impracticable in most instances to spin and test enough skeins of each of several counts of yarn to determine the actual count-strength product curve for that cotton and for that twist angle. But if the slope of the curve were known, together with the location of one point on the curve, the correction of the yarn strengths to the specified count would become a simple matter.

In a recent study conducted by the Bureau of Agricultural Economics a large quantity of yarn-strength and yarn-size data were analyzed. This study involved more than 70,000 individual skein tests made under standard atmospheric conditions and representing 425 different cottons. All of the yarns had been spun at the Bureau's spinning laboratory.[3] These yarns (spun with medium-warp twists) represented eight staple-length groups ranging from thirteen-sixteenths of an inch to 1³⁄₃₂ inches. The data from these cottons were

[3] In cooperation with the Textile School, Clemson Agricultural College, Clemson, S. C.

81442°—36——2

sorted into the eight staple-length groups, and the count-strength products were plotted for 22s, 28s, 36s, and 44s yarn. It was observed that the four points plotted for each staple length formed a curve that described a straight line, except for minor deviations. By the use of the method of least squares (regard being given to the proper weighting of the data) straight lines were fitted to each group of data. These lines were practically parallel. The average slope formed by these curves was calculated and found to be such that 1 count unit was equivalent to 21.7 count-strength product units.

Using this value as a constant, the following formula[4] was derived:

$$S_2=\frac{C_1S_1-(C_2-C_1)(21.7)}{C_2}$$

in which C_1=the observed count
C_2=the specified or "nominal" count
S_1=the observed skein strength
S_2=the corrected skein strength.

To illustrate the use of the formula, it will be assumed that a skein of 20.75s yarn has a breaking strength of 110.0 pounds and that the specified count is 22s.

$$S_2=\frac{110\times20.75-(22-20.75)(21.7)}{22}=102.5 \text{ pounds}$$

(With the usual formula the result would be 103.8 pounds.)

Examination of this formula will show that it consists of the generally accepted formula, $\frac{C_1S_1}{C_2}$, to which has been attached a correction, namely, $\frac{-(C_2-C_1)(21.7)}{C_2}$. It is the numerator of this appendage to the formula that moves the point *b* in figure 2, for example, downward and to the right rather than horizontally to the right, thus correcting the strengths with due regard to the true relation of count to count-strength product. In a number of cases, when the data permitted, the curves were extended on the abscissa to 50s and to 60s. The plotted points still formed practically straight lines. Thus it appears that the formula should be applicable for all numbers between 20s and 60s, and in many instances it would undoubtedly be permissible to extend this range, particularly in the lower counts.

The values of the constants used in the conversion formula, as calculated for each staple length, are as follows:

Staple length (inches)	*Count-strength units*
13/16	25.1
7/8	23.1
15/16	23.3
1	21.2
1 1/16	21.3
1 1/8	17.4
1 3/16	17.3
1 1/4	15.9
Average	21.7

The average of the count-strength units was weighted with regard to number of items of each length.

[4] J. M. Cook, W. H. Gray, and L. O. Buchanan of the Bureau of Agricultural Economics, assisted in the compilation of the data from which the formula was developed.

These values of constants range from 25.1 for the $1\frac{3}{16}$-inch staple to 15.9 for the $1\frac{1}{4}$-inch staple. Although there is a noticeable trend toward somewhat lower values of the constant for the longer staple lengths, it is observed that the constants for the three longest staples listed appear somewhat lower than might have been expected. It should be explained that the number of observations upon which the values for these lengths are based is somewhat lower than those for the shorter lengths.

The effects of using both the highest and the lowest values of the constant instead of the average value, 21.7, will be determined, in the same example as was used above:

$$\frac{110\times 20.75-(22-20.75)\ (25.1)}{22}=102.3 \text{ pounds (using highest value)}$$

$$\frac{110\times 20.75-(22-20.75)\ (15.9)}{22}=102.8 \text{ pounds (using lowest value)}$$

The difference, 0.5 pound, between the two results is small. Evidently any slight changes in the mean value of the constant, 21.7, that might result from the use of additional data, would be negligible.

APPLICATION

In addition to its value in correcting yarn strengths to specified counts, the formula is useful in estimating fairly closely, on the basis of any count and strength that may have been determined already, the probable skein strength of any other count of yarn into which a particular cotton may be spun. For example, a spinner may be making 60s warp yarn from a cotton and may wish to know what the probable strength of 50s or 40s warp would be. Actual trials have shown that by using this formula the probable strength can be predicted with considerable accuracy in most instances.

Table 1 is presented to show this application of the formula to the results from six cottons selected at random from a report published by the United States Department of Agriculture.[5] The second column shows the actual corrected strengths for 28s warp yarn. The third, fourth, and fifth columns show the strength of 28s yarn predicted from the strengths and counts of yarn spun to 22s, 36s, and 44s. The average relative deviations are seen to range from +0.88 percent for the strengths estimated from the 44s to −1.94 percent for those estimated from the 22s.

It is recognized that the usual formula, involving inverse proportionality, cannot be used to estimate with any approach to accuracy the yarn strengths over a wide range of counts. The data in the sixth, seventh, and eighth columns of table 1 show the errors introduced by such a method. The large discrepancies between the estimated strengths and actual strengths are at once apparent. The average relative deviations range from +4.12 percent for the strengths estimated from 22s to −15.34 percent for those from 44s.

[5] WILLIS, H. H., and MCNAMARA, H. C. SPINNING TESTS OF SOME TEXAS-GROWN VARIETIES OF COTTON (CROPS OF 1923, 1924, AND 1925). PRELIMINARY REPORT. U. S. Dept. Agr. 1928. [Mimeographed.]

TABLE 1.—*Actual skein strengths of 28s yarn and those calculated by both new and old formulas from widely different counts*

Variety tested and length of staple (inches)	Actual strengths of 28s yarn	Strengths for 28s yarn calculated from strengths of observed counts					
		By new formula			By old formula		
		22s	36s	44s	22s	36s	44s
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Kekchi, 1⅛	78.6	75.7	80.5	80.0	80.4	74.3	67.6
Lone Star, 1	74.2	74.2	75.0	74.8	78.8	68.8	62.4
Acala, 1⅛	84.9	82.8	88.2	87.5	87.4	82.0	75.1
Lone Star, 1 1/16	75.7	74.6	77.9	78.4	79.2	71.7	66.0
Mebane, 15/16 to 1	71.4	70.5	72.5	72.9	75.1	66.3	60.5
Rowden, 1	73.9	72.0	71.1	69.1	76.7	64.9	56.7
Average	76.45	74.97	77.53	77.12	79.60	71.33	64.72
Average deviation from actual		−1.48	+1.08	+0.67	+3.15	−5.12	−11.73
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Deviation from actual		−1.94	+1.41	+0.88	+4.12	−6.70	−15.34

In using the proposed formula for such purposes it is necessary to observe two points, namely, that the twist multiplier of the two yarns should be the same or nearly so, and that the count of yarn should not be extended beyond the practical spinning limits for the particular cotton being used. For instance, the method should not be used to determine the strength of 60s spun from a cotton of ⅞-inch staple, since such a count cannot be spun commercially from cotton of ⅞-inch staple length.

Because only a relatively small quantity of combed-yarn data was available, the results of tests of carded yarns alone were employed in developing the formula, but actual tests have shown that the formula can be applied to combed-yarn data with equally satisfactory results.

Preliminary studies have shown that the same general type of relationship exists between the count-strength product and the count of a single strand of yarn. It is believed that a formula developed from appropriate data in a similar manner to that employed for the skein-conversion formula should be applicable to single-strand tests.

USE OF FORMULA IN MILLS AND TESTING LABORATORIES

In mills and testing laboratories in which a considerable amount of testing is done on a few counts of yarns, a series of tables similar to table 2 will be found useful. This table is used to correct each pair of strength and size observations in a series, rather than the average strength and size for the series.

To illustrate the use of table 2, it will be assumed that a skein of yarn is found to break at 85 pounds and to size 22.75s. The specified count will be considered as 22.00s. In the column headed 85 pounds the value, 88.6, is found in the line for 22.75s. This is the strength in pounds converted to that for 22.00s.

Such tables can easily be worked out from the formula on page 10. From a study of previous tests, the approximate range of size and strength needed for a specified count can be determined, and a blank form for the desired table prepared. For any observed count, say, the lowest to be included, the corrected break for the lowest observed

TABLE 2.—*Sample table for use in converting observed skein strengths to those for a specified size (22.00s)* [1]

Observed count size	Strength of 22s yarn when observed strength is—									
	80 pounds	81 pounds	82 pounds	83 pounds	84 pounds	85 pounds	86 pounds	87 pounds	88 pounds	89 pounds
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
20.00	70.8	71.7	72.6	73.5	74.4	75.3	76.2	77.1	78.0	78.9
20.25	71.9	72.8	73.8	74.7	75.6	76.5	77.4	78.4	79.3	80.2
20.50	73.1	74.0	74.9	75.9	76.8	77.7	78.7	79.6	80.5	81.4
20.75	74.2	75.2	76.1	77.1	78.0	78.9	79.9	80.8	81.8	82.7
21.00	75.4	76.3	77.3	78.2	79.2	80.2	81.1	82.1	83.0	84.0
21.25	76.5	77.5	78.5	79.4	80.4	81.4	82.3	83.3	84.3	85.2
21.50	77.7	78.7	79.6	80.6	81.6	82.6	83.6	84.5	85.5	86.5
21.75	78.8	79.8	80.8	81.8	82.8	83.8	84.8	85.8	86.8	87.7
22.00	80.0	81.0	82.0	83.0	84.0	85.0	86.0	87.0	88.0	89.0
22.25	81.2	82.2	83.2	84.2	85.2	86.2	87.2	88.2	89.2	90.3
22.50	82.3	83.3	84.4	85.4	86.4	87.4	88.4	89.5	90.5	91.5
22.75	83.5	84.5	85.5	86.6	87.6	88.6	89.7	90.7	91.7	92.8
23.00	84.6	85.7	86.7	87.8	88.8	89.8	90.9	91.9	93.0	94.0
23.25	85.8	86.8	87.9	88.9	90.0	91.1	92.2	93.2	94.2	95.3
23.50	86.9	88.0	89.1	90.1	91.2	92.3	93.3	94.4	95.5	96.5
23.75	88.1	89.2	90.2	91.3	92.4	93.5	94.6	95.6	96.7	97.8
24.00	89.2	90.3	91.4	92.5	93.6	94.7	95.8	96.9	98.0	99.1

Observed count size	Strength of 22s yarn when observed strength is—									
	90 pounds	91 pounds	92 pounds	93 pounds	94 pounds	95 pounds	96 pounds	97 pounds	98 pounds	99 pounds
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
20.00	79.8	80.8	81.7	82.6	83.5	84.4	85.3	86.2	87.1	88.0
20.25	81.1	82.0	83.0	83.9	84.8	85.7	86.6	87.6	88.5	89.4
20.50	82.4	83.3	84.2	85.2	86.1	87.0	88.0	88.9	89.8	90.8
20.75	83.7	84.6	85.5	86.5	87.4	88.4	89.3	90.3	91.2	92.1
21.00	84.9	85.9	86.8	87.8	88.7	89.7	90.6	91.6	92.6	93.5
21.25	86.2	87.2	88.1	89.1	90.1	91.0	92.0	93.0	93.9	94.9
21.50	87.5	88.4	89.4	90.4	91.4	92.3	93.3	94.3	95.3	96.3
21.75	88.7	89.7	90.7	91.7	92.7	93.7	94.7	95.7	96.6	97.6
22.00	90.0	91.0	92.0	93.0	94.0	95.0	96.0	97.0	98.0	99.0
22.25	91.3	92.3	93.3	94.3	95.3	96.5	97.3	98.3	99.4	100.4
22.50	92.5	93.6	94.6	95.6	96.6	97.7	98.7	99.7	100.7	101.7
22.75	93.8	94.8	95.9	96.9	97.9	99.0	100.0	101.0	102.1	103.1
23.00	95.1	96.1	97.2	98.2	99.3	100.3	101.4	102.4	103.4	104.5
23.25	96.3	97.4	98.5	99.5	100.6	101.6	102.7	103.7	104.8	105.9
23.50	97.6	98.7	99.8	100.8	101.9	103.0	104.0	105.1	106.2	107.2
23.75	98.9	100.0	101.0	102.1	103.2	104.3	105.4	106.4	107.5	108.6
24.00	100.2	101.2	102.3	103.4	104.5	105.6	106.7	107.8	108.9	110.0

[1] Conversions based on formula presented in this bulletin.

break is determined, as is the increment to be added to it to give the next consecutive break. Simply by adding this increment once for each consecutive break, the corrected breaks are determined for all of the observed breaks, proceeding from left to right across the table. A similar procedure is then followed for the next observed count.

For a given observed count (representing one line across the table) the increment may also be determined in the following way: The form of the conversion formula may be changed to the form

$$S_2=\frac{C_1S_1}{C_2}-\frac{(C_2-C_1)21.7}{C_2}$$

without affecting its value. An examination of this formula will show that, if the observed count alone is changed, the only factors in the formula to be changed are the values S_2 and S_1. Thus, if the value of S_2 is determined for a given count and a particular observed strength, it is necessary only to add an amount equal to the difference between

the observed strengths, multiplied by the observed count, and divided by the specified count. This result is the increment to be added each time the observed strength is increased one unit from left to right in the table.

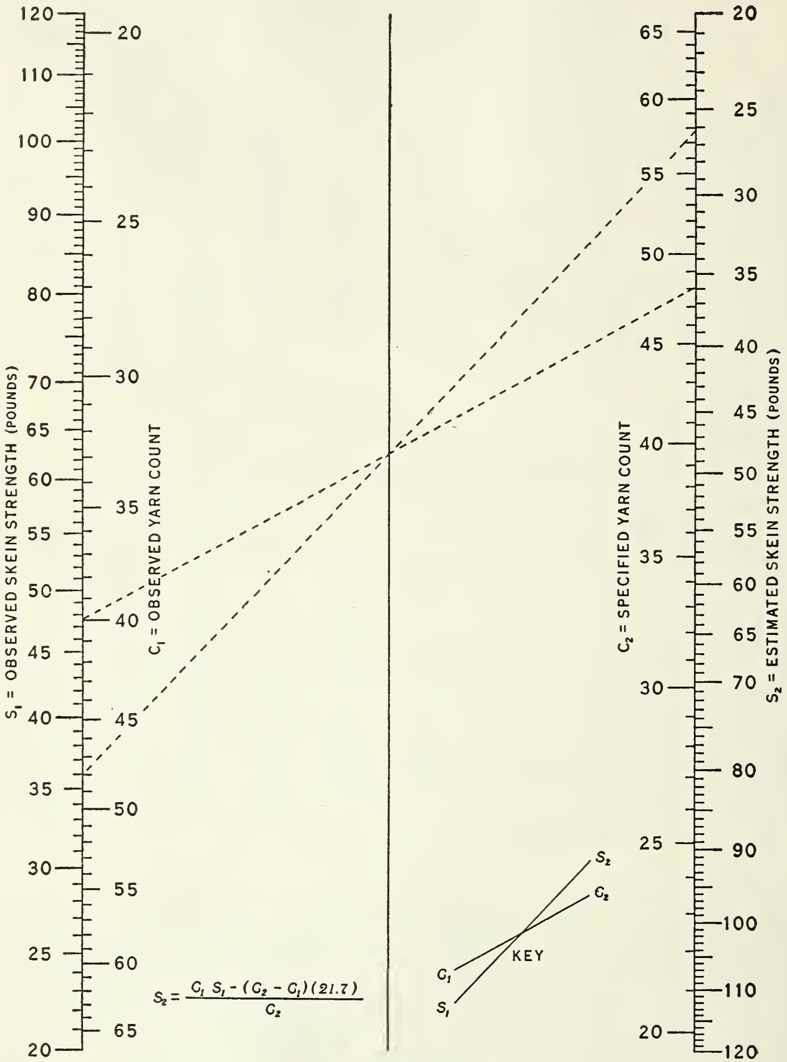

FIGURE 4.—CHART FOR FINDING SKEIN STRENGTH OF A SPECIFIED YARN.

Lay a straightedge on the scales for observed count C_1 and specified count C_2 and note the point of intersection with the line in the center. On this point as a center, move the straightedge to the point on the scale for observed strength S_1 and read the value sought on the scale for estimated skein strength S_2. The results will be comparable with those obtained by application of the formula or of tables made from it.

It has been pointed out previously that the tables are for use in correcting individual pairs of observations rather than averages. This is done for two reasons. (1) It provides a single series of corrected breaks, for which the average strength and the dispersion of

the strengths can be determined. The latter measure is particularly valuable, since it permits the reliability of the average to be calculated. (2) If the average strength and the average size are determined, and the corrected strength is calculated from these, the result will not be the same as the average of the individual corrected breaks. The same is also true of the usual method of correcting skein breaks. A consideration of the matter will show that the method in which the individual skein tests are converted is the correct one. Unless there is a considerable disparity between the specified and the observed count, the error introduced by correcting the averages is small.

Figure 4 is an alignment chart for the rapid solution of the formula.[6] With a straightedge the correct values for C_1 and C_2 are connected, and the point where this line crosses the center or turning scale is marked with a light pencil line. The straightedge connecting S_1 with the point on the turning scale will pass through the correct value for S_2, or the corrected strength, on the extreme right-hand scale. This chart is especially useful in estimating closely and quickly the probable strengths of yarns covering a considerable range of count.

The following example will illustrate the use of this chart: It will be assumed that a particular cotton is spun into 40s yarn with an average strength of 36 pounds per skein. It is desired to know the probable strength of 48s spun from the same cotton with the same twist multiplier. With a straightedge, the point representing 40s on the inner left-hand scale is connected to that for 48s on the inner right-hand scale. This position of the straightedge is represented by one of the broken lines in figure 4. The point at which this line crosses the center or turning scale is marked lightly in pencil, and the straightedge is shifted to connect this point with the value, 36 pounds, on the outer left-hand scale. The straightedge is seen to pass through the value, 26 pounds, on the outer right-hand scale. This is the probable strength of 48s, as given by the formula.

An alignment chart of the type shown in figure 5 is somewhat easier to use when strengths are to be corrected for a single specified count. This chart has been prepared for converting skein strengths to the estimated strengths for 28s yarn. If desired, a chart of this type may be prepared for each standard count that may be used in a particular mill, instead of the tables previously mentioned.[7] To use the chart, a straightedge is placed on the chart in such a manner as to connect the values for the observed yarn count and the observed skein strength. The straightedge passes through the value for the strength corrected for 28s on the inner scale.

SUMMARY

The degree of variability in the size of cotton yarn and the consequent need for a method of converting skein strengths to those for a specified or nominal size are here discussed. A survey of the literature shows that the results of most spinning tests are converted or "corrected" by one of two methods, both of which are based upon

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[6] The writer wishes to acknowledge the assistance of D. C. Sheldon, Clemson Agricultural College, in preparing the alignment chart (fig. 4).
A large working-size copy of this chart will be mailed to anyone who sends a request to the Division of Cotton Marketing, Bureau of Agricultural Economics, U. S. Department of Agriculture, Washington, D. C.

[7] Instructions for the preparation of alignment charts may be found in standard textbooks on the subject (*8, 10*).

the assumption that within sufficiently wide limits skein strength and size are inversely proportional. The discrepancy between this

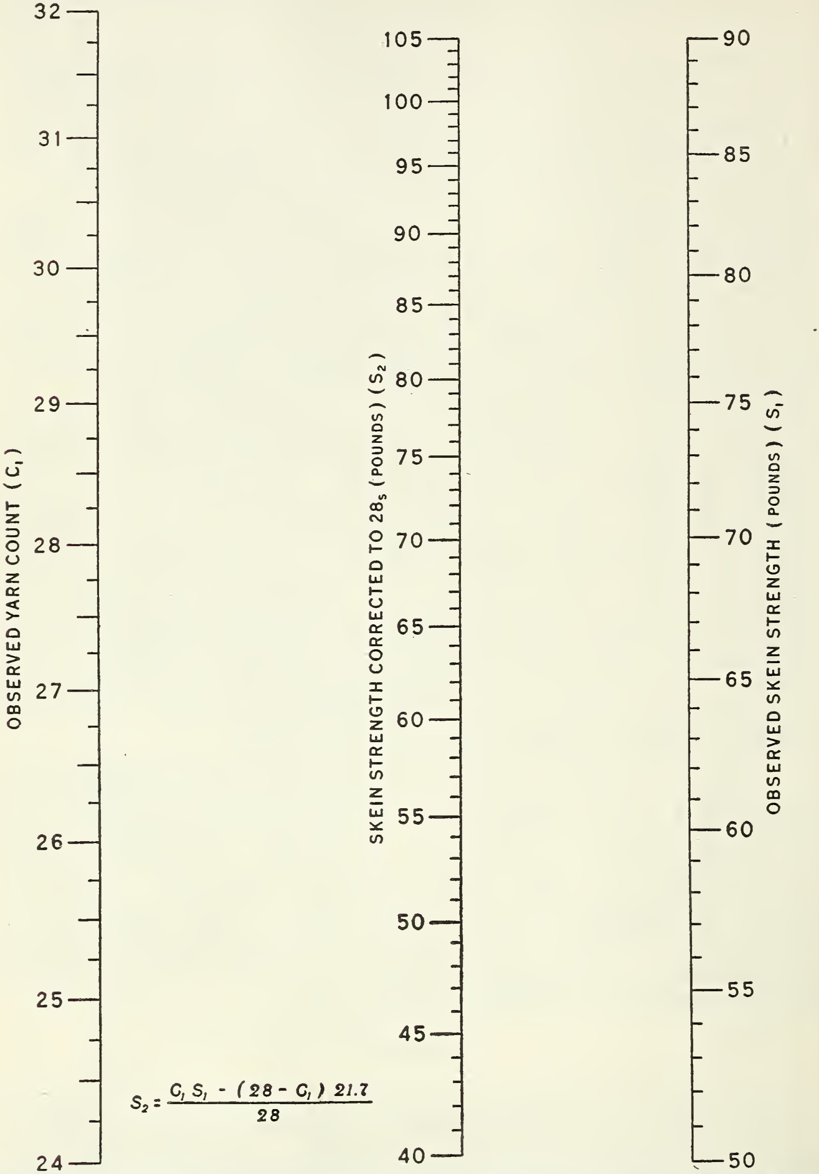

FIGURE 5.—FORM OF ALIGNMENT CHART FOR USE WITH A SINGLE SPECIFIED COUNT.

This form is somewhat easier to use than the form shown in figure 4.

assumption and the actual fact is pointed out and explained graphically.

An empirical formula based upon the results of more than 70,000 individual skein tests is presented, by the use of which yarn

strengths can be converted to those for specified sizes with due regard to the true relations of skein strength to size. This formula is as follows:

$$S_2 = \frac{C_1 S_1 - (C_2 - C_1)(21.7)}{C_2}$$

C_1 being the observed count; C_2, the specified or "nominal" count; S_1, the observed skein strength; and S_2, the converted skein strength.

In addition to the use mentioned, the formula is adapted to the estimation of the probable strengths of yarns of various sizes, using observed strength and size data for one particular count as a basis. It has additional value in that it provides a means of placing test results of different spinning laboratories on the same count basis, thus permitting direct comparisons.

Through its use economies in spinning tests can be effected by spinning only extreme counts and interpolating for midcounts.

Although developed from carded yarn data, the conversion formula can be applied also to combed-yarn data with equally satisfactory results.

Preliminary studies have indicated that a formula developed by the same principle should be applicable to the results of single-strand tests.

A sample table, adapted to mill and laboratory use in cases in which a considerable amount of test work is conducted on a few counts of yarn, is shown. A simple method of preparing similar tables is explained.

Alignment charts for the quick solution of the formula are presented.

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